The Effects of Surgical Masks on Speech Perception in Noise

Research Thesis

Presented in partial fulfillment of the requirements for graduation *with research distinction* in Speech and Hearing Science in the undergraduate colleges of The Ohio State University

by

Kelsi Jo Wittum

The Ohio State University

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Project Advisors: Dr. Lawrence Feth, Ph.D., Department of Speech and Hearing Science and
Dr. Evelyn Hoglund, Ph.D., Department of Speech and Hearing Science

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Christina Roup Departmental Representative	[signature] Departmental Representative
Evelyn Hoglund Optional signature for 3rd member (if applicable)	[signature] Optional signature for 3rd member (if applicable)

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Abstract

Surgical masks and blood shields worn by anesthesiologists and surgeons in hospital operating rooms may negatively impact speech communication and put patients at risk. Young adult subjects listened to sentences from the Speech Perception in Noise test, SPIN, (Bilger et al., 1984) recorded by a male and female talker. All eight SPIN lists were recorded under three different speaking conditions: 1) speaking normally without any obstruction, 2) wearing a typical surgical mask, and 3) wearing a surgical mask with an attached blood shield. Multi-talker babble was mixed with the SPIN sentences at the signal-to-noise ratio of 0 dB to simulate conversation in noisy environments. Speaker gender and recording conditions were counterbalanced across listeners to control for learning and fatigue effects. SPIN test scores for each of the three types of recordings and both talker genders were compared in order to determine the degradation that blood-shields and surgical masks may have on speech communication in the operating room. The data suggests that surgical masks, in particular the blood shields, negatively impact speech communication. Percent correct is the highest for the unmasked condition, followed by the masked condition, and poorest in the mask and attached blood shield condition.

Chapter 1

Introduction and Literature Review

Introduction

A hospital surgical suite is a place that should be without faults. A huge number of surgeries take place every day throughout the United States and the patients expect that there will not be any problems that will affect their procedure. One potentially serious problem in the surgery room that could have an important impact on the patient is poor communication between the health professionals in the operating room due to obstructed hearing caused by difficult listening conditions. A hospital operating room is a very noisy place due to the machines, monitors, and surgical tools that are in constant use. There are always beeps, alarms, and the roar of surgical tools. Additionally, in order to maintain a sterile environment, the floors and walls of an operating room are made of tile, with no carpet, drapes, or any other sound absorbing materials. The loud sounds of an operating room therefore are not absorbed, but instead echo off of the surfaces of the operating room, adding to the noisy environment.

Anesthesiologists and surgeons at Nationwide Children's Hospital in Columbus, Ohio, have expressed serious concerns about the noise level of the operating rooms in which they work. These professionals have complained that it is sometimes difficult to hear one another during surgeries, which puts patients at unnecessary risk. Given the importance and intensity of their work, it is absolutely essential that anesthesiologists and surgeons be able to hear each other clearly at all times during surgery. A lack of the ability to hear properly could result in mistakes and misinterpretations between the surgeons, anesthesiologists, and other health professionals which in turn may harm the patient.

One factor that may contribute to speech communication problems in surgery is the surgical masks and blood-shields that health professionals must wear. These procedure masks cover the lower portion of the face, the mouth and nose, and serve to prevent the transmission of bacteria and fluids between the patient and the health professional, protecting both. While medically important, these masks may muffle or block speech of the person who is wearing the mask. This obstruction could result in quieter or distorted speech reaching the listener's ears. It may well be more difficult to hear someone who is wearing a surgical mask or a surgical mask and a blood-shield, than someone who is speaking without these physical impediments. In an operating room full of sounds of the surgical equipment and echoes, it is important to determine if surgical masks and blood-shields negatively impact the hearing of health professionals, and put patients at needless risk.

Literature Review:

There have been several studies that have investigated the issue of high noise levels in operating rooms. Kracht et al. (2007) measured the sound levels of operating rooms during surgeries at Johns Hopkins Hospital. The investigators measured the sound level of surgeries in all branches of medicine, such as neurology, cardiology, orthopedics, and plastic surgery and took special care to preserve the normal situation for each surgery. A Larson Davis System 824 sound level meter was used to collect the data. Data analysis allowed them to conclude that surgeries had very high sound levels. Sound pressure levels at Johns Hopkins Hospital were found to average between 55 and 70 dB(A) with significant sound peaks, some reaching intensities as high 110 and 120 dB, during surgical procedures. According to the authors, the high sound pressure levels in the operating room were not at levels loud enough to cause significant permanent hearing loss, however the fact that there were high sound pressure peaks (at least 110 dB) present was a cause for concern. Additionally, they were concerned about the impact of high sound pressure levels on speech communication upon analysis of their results. In general, clear speech communication requires at least a 15 dB signal-to-noise ratio. The sound pressure levels of operating rooms during surgery in this study suggested that in order for health professionals to communicate clearly in this noisy environment, they would have to speak at a level of 70-85 dB(A) [normal speech levels are 55-65 dB(A)]. Additionally, the high sound pressure peaks in noise often impeded communication, making it temporarily more difficult to understand speech. Ultimately, the Kracht et al. study demonstrates that operating rooms are inherently very noisy places in which speech communication is difficult.

Falk et al. (1973) focused on the level of hospital noise as well. In this study, a Bruel and Kjaer Precision Sound Level Meter, Type 2203 with octave band analyzer was used to measure sound pressure levels in infant incubators, a recovery room, and two rooms of an acute-care unit.

Twenty-four hour measurements were made and the various noise sources were noted. The mean levels of sound in the incubator were 65.6 dB(A), 57.2 dB(A) in the recovery room, 60.1 dB(A) in the first acute-care unit, and 55.8 dB(A) in the second acute-care unit. The authors noted that in the recovery room as well as in the acute-care units, the noise levels were correlated with the number of hospital staff present in the room. A high number of staff in the room resulted in a high level of noise. They concluded that the noise levels in these rooms contributed to sleep deprivation of patients. This study did not measure the sound level in operating rooms; however the results from the study suggest that if operating rooms had been measured, high sound levels would have been found. Given the high sound pressure level tools used in operating rooms along with poor room acoustics, it can be assumed that these rooms would have even higher noise levels than the acute-care units and recovery room examined in the Falk et al study.

Murthy et al. (1995) analyzed the detrimental effects of operating room noise levels on measures of mental performance. In this experiment, the authors measured the noise levels in operating rooms using the Precision Integrating Sound Level Meter, Bruel and Kjaer Type 2230 in order to determine which operating rooms had the highest noise levels. Orthopedic surgery, general surgery, cardiothoracic surgery, emergency-operation surgery, and neurosurgery were found to be the operating rooms with high noise levels and thus they were studied in more detail. Audio recordings were made of these operating rooms using microphones placed 25 centimeters from the anesthesiologist. Twenty anesthesia residents were then given cognitive function tests: the Trail Making Test, Digit Symbol Test, and Benton Visual Retention Test. One week later, these same residents were given the same exact tests, while the recorded operating room noise was played through loud speakers. The results of this study found that exposure to noise levels equivalent to that of an operating room resulted in deterioration in mental efficiencies and shortterm memory loss. Given the highly intense nature of the work of anesthesiologists, this type of mental lapse or memory loss could result in serious mistakes during the surgical procedure. As suggested by this study, a noisy surgery room environment has detrimental effects on both speech communication and mental performance.

Mendel et al. (2008) conducted a study to determine if surgical masks had a detrimental effect on speech perception in dental offices amongst individuals with normal hearing and with hearing impairments. The study served as a partial model for the current experiment. Sixteen lists of the Connected Speech Test were randomly selected to be recorded. Each list contained ten sentences made up of related context and included twenty-five target words to be scored during the test. A male professional radio broadcaster prepared digital recordings of these selected lists with and without a surgical mask present. Eight lists were recorded while the speaker was not wearing a mask and eight lists were recorded while the speaker was wearing the surgical mask. A recording of the noise from a dental hand drill in a dental office in the middle of the morning was also prepared. The microphone was placed on the side of the patient's chair, approximately three to six inches from the patients head.

Thirty adults participated in the Mendel et al. (2008) study: 15 participants had normal hearing and 15 participants had a hearing impairment (hearing thresholds equal to or poorer than 25 dB HL). Study participants were seated in a sound-treated room and were presented recordings through a GSI 61 audiometer at a comfortable listening level through a Bose speaker. The recordings were then presented to the study participants in four conditions: four lists recorded without a mask, presented in quiet; 2) four lists recorded without a mask, presented in noise (the recording of the hand drill); 3) four lists recorded with a mask, presented in quiet; and 4) four lists recorded with a mask, presented in the same recorded noise. Subjects listened to the recordings and repeated what they heard. If all of the words in each sentence were repeated correctly, the response was considered correct.

Mendel et al. (2008) reported that for listeners with normal hearing, the speech perception percent correct with the mask present was 98.77%, statistically better than speech perception percent correct without the mask which was 97.83%. Similar results were reported for listeners with hearing loss; the speech perception score with the mask present was 93.20% and 92.13% without the mask. From these results, the authors concluded that the presence of a surgical mask did not have a detrimental effect on speech understanding in either the normal hearing or hearing-impaired groups in this study.

While the Mendel et al. (2008) study concluded that the presence of a surgical mask was not detrimental to speech perception, there are several limitations to this study that need to be considered before it can be concluded that surgical masks do not effect speech perception. The study solely focused on a dental office and thus, this study did not examine any other medical settings. Dental offices are typically a much quieter environment then hospital operating rooms or emergency rooms. This study also only used the sound of a dental drill as the background noise. In other medical settings, many other tools are used and in cases such as surgery, multiple tools are used at once. If this test had been run using a different background noise, such as the background noise of a hospital operating room, the results may well have been different. The dental drill also produces a high frequency sound, therefore only the effect of a high frequency noise on speech was tested in this study. Many other medical tools such as bone-saws and other tools used in major surgeries produce low frequency sounds and therefore the effect of low frequency noise on speech should be tested as well. This study also focused solely on surgical masks and did not study the effect of a surgical mask plus a blood-shield. A more thorough study which examines the effect of a surgical mask plus a blood-shield is necessary to see if this combination results in reduced speech perception in noise as blood-shields are worn frequently in certain medical settings. It is important to note that in the Mendel et al. (2008) study, the signal-to-noise ratio was +5 which meant that the speech stimuli were presented 5 dB HL higher than the noise. In many medical settings, the noise is louder than or equivalent to the level of speech and therefore having a +5 signal-to-noise ratio is not necessarily a very realistic representation. The +5 signal-to-noise ratio may have made it very easy to understand the speech stimuli in the Mendel et al. (2008) study because the speech stimuli were presented at a higher level than the noise of the dental drill. Further research in this area should examine speech perception performance when the noise and speech stimuli are presented at the same level (a signal-to-noise ratio of 0 dB). Given these limitations with the Mendel et al. (2008) study, it cannot be concluded that surgical masks negatively affect speech understanding without further research.

The purpose of the present experiment was to determine what effect the surgical masks and blood-shields worn by health professionals had on speech perception in noise. The two null hypotheses for this experiment were: 1) listener performance on a standard test of speech perception in noise will not be affected by the use of a surgical mask or a surgical mask plus blood-shield, and 2) listener performance on a standard test of speech perception in noise will not be affected by the gender of the speaker. The results of this study will be shared with health professionals at Nationwide Children's Hospital in an attempt to improve speech communication in operating rooms.

Chapter 2

Methods

Stimuli

The stimulus material used for the experiment was the Speech Perception in Noise (SPIN) test (Bilger et al., 1984). The SPIN test is a standardized test that measures speech perception performance in background noise. The SPIN test is comprised of eight lists, each made up of 50 different sentences, and in each sentence the last word is the target word. This test is a word recognition task in which the listener is responsible for repeating the last word of each sentence. Twenty-five of the sentences have strong context (high predictability) and 25 of the sentences provide little or no context (low predictability). In high predictability sentences, the last word matches the content of the sentence, such as, “Stir your coffee with a spoon.” In low predictability sentences, the last word does not match the content of the sentence, for example, “Bob could have known about the spoon.” As shown from these examples, each target word is used in both a high predictability and low predictability sentence. The SPIN test lists are arranged so that the high predictability and low predictability sentences are randomly distributed throughout the list. This ensures that the listener will never know the order in which the high predictability and low predictability sentences are presented. The SPIN test was selected for this experiment for several reasons. The eight SPIN lists are all statistically equivalent, therefore regardless of which list is used, the same results would be expected. The SPIN test also provides an initial simulation of a hospital operating room in which health professionals must pick out speech sentences amidst a noisy background. The SPIN test is also fast and easy to administer and can be completed by the listener in one testing session.

The SPIN test sentences were mixed with a recording of multi-talker babble. Multi-talker babble consists of male and female talkers speaking random sentences at the same time, making it difficult to pick out what one particular speaker is saying at any given time. In this experiment, the multi-talker babble represented the background noise of a noisy hospital operating room. Multi-talker babble was selected to serve as the background noise for this project as it is a standardized background noise.

Subjects

Subjects for the experiment were 21 normal hearing young female adults (ages 20-23 years). The subjects were students majoring in Speech and Hearing Science at the Ohio State University, and because this major is comprised mainly of females, all of the subjects who participated were females. Normal hearing was established through standard audiometric tests using an Interacoustics AC33 audiometer. For this test, normal hearing was defined as hearing sensitivity better than 20 dB HL across all octave frequencies, 250-4,000 Hz in both ears. After determining normal hearing, subjects were seated in a sound-attenuating booth and the SPIN test sentences and multi-talker babble were presented monaurally to the right ear through headphones. The SPIN test sentences were presented through Channel 1 of the audiometer and multi-talker babble was presented through Channel 2 of the audiometer. The audiometer mixed the SPIN test sentences and the multi-talker babble at a signal-to-noise ratio of 0 dB. The 0 dB signal-to-noise ratio was selected as it simulated a hospital operating room in which the noise of the machines and surgical tools is at the same level as the speech of the health professionals. Both the SPIN test sentences and the multi-talker babble were presented at a level of 60 dB HL. On average, the hearing screening and experiment took subjects two hours to complete. Subjects were compensated twenty dollars for their participation.

Procedures

For this experiment, six complete recordings of the SPIN test were made by professional speakers at FutureCom Technologies, Inc., in Gahanna, Ohio. The eight SPIN test lists were recorded by professional male talker and female talkers under three different speaking conditions. First, the recording was made with the speaker unmasked, second the recording was made with the speaker wearing a surgical mask, and finally the recording was made with the speaker wearing a surgical mask with blood-shield. Figure 1 illustrates the surgical mask and surgical mask with the blood-shield that health professionals wear in hospital operating rooms. These are the masks that were worn by the professional speakers when they prepared the recordings of the SPIN test sentences for this experiment. As the pictures demonstrate, the surgical mask clearly covers the mouth and nose and the blood-shield covers the majority of the face.

Using Adobe Audition software, compact discs were created with the digital recording of the SPIN test sentences on channel 1 and the standardized multi-talker babble on channel 2. Before running the 21 subjects, the audiometer sound level was calibrated using a Larson Davis 824 Sound Level Meter and a KEMAR mannequin (Russotti. et al., 1988). A 1000 Hz calibration tone on each channel of the CD was played and the audiometer was manually adjusted to read 0 VU for both channel 1 and channel 2. Once the audiometer was at 0 VU for both channels, the calibration tone was played through headphones (Telephonics TDH-39P with MX41/AR Cushion) placed over an ear simulator in KEMAR. The calibration tone for Channel 1 measured 80.5 dB SPL and the calibration tone for Channel 2 was 81.3 dB SPL. The two channels of the audiometer were within 1 dB of each other and therefore were closely matched. The level of the SPIN test sentences ranged from 61 to 65 dB LEQ and the level of the multi-talker babble was 68 dB LEQ.

Listeners were seated individually in the sound attenuating booth and were asked to wear the headphones. The listeners were asked to listen for the SPIN test sentences amidst the multi-talker babble and repeat the last word of the sentence. If the listener did not hear the last word of the SPIN test sentence, he or she was instructed to not respond and instead remain quiet. The presentation of the SPIN test sentences was counterbalanced in order to ensure that no subject heard the SPIN tests sentences in the exact same order. For example, the presentation order for listener one was male unmasked, female unmasked, male masked, female masked, male shield, female shield while the presentation order for listener two was female shield, male unmasked, female unmasked, male masked, female masked, male shield. Counterbalancing and randomizing the presentation order of the SPIN test sentences also prevents the data from being biased due to listener fatigue.

The experimenter listened to the SPIN sentences unmasked only (without the multi-talker babble) outside of the sound attenuating booth. The experimenter monitored each listener response and compared the listener response to the list of the correct target words for each SPIN sentence presented. If the listener stated the correct target word, the experimenter recorded a score of a 1. If the listener stated an incorrect target word, the experimenter recorded a score of a 0 and recorded the incorrect word that was said. The percent of correct responses for both high predictability and low predictability sentences were calculated for each individual participant. For example, in order to calculate the percent correct of high predictability sentences, the number of high predictability sentences the listener got correct was tallied and then divided by 25 because there are 25 total high predictability sentences. The same thing was done for low predictability sentences. These percent correct scores for high and low predictability were calculated for each SPIN list for each listener. The mean percent correct and standard deviation of all participants were then calculated for male and female talkers, unmasked, masked, and shield speaking condition, and for high predictability and low predictability sentences.

Figure 1: Surgical mask and surgical mask and blood-shield worn by health professionals in hospital operating rooms.
Downloaded March 26, 2013 from http://www.emedhealthcare.com/masks/.

Chapter 3

Results

Figure 2 shows the average percent correct varied greatly based on the speaking condition. The overall percent correct was best for the unmasked speaking condition, 48.5%, followed by the masked speaking condition, 33.1%, followed by the mask plus blood-shield speaking condition, 20.9% correct. The average percent correct also varied greatly based on the gender of the speaker. In all three speaking conditions and for both high predictability and low predictability sentences, female speakers had a higher average percent correct than male talkers. The average percent correct for female speakers was 47.1% correct while the average percent correct for male speakers was 21.2%. The average percent correct was also affected by the context of the SPIN test sentence. High predictability sentences had a greater percent correct than low predictability sentences in each speaking condition and both male and female speakers. The average percent correct for high predictability sentences was 39.2% while the average percent correct for low predictability sentences was only 28.4% correct.

Given these data, statistical analyses using a three-way, repeated measures analysis of variance was performed. The ANOVA indicated that each of the three main effects tested in this experiment, the speaking condition, the gender of the speaker, and the sentence context, were all significant at the 0.01 level. An analysis of the interactions of these three effects was also performed. It was determined that the gender by mask effect was statistically significant at the 0.01 level, but neither of the other two interactions was statistically significant.

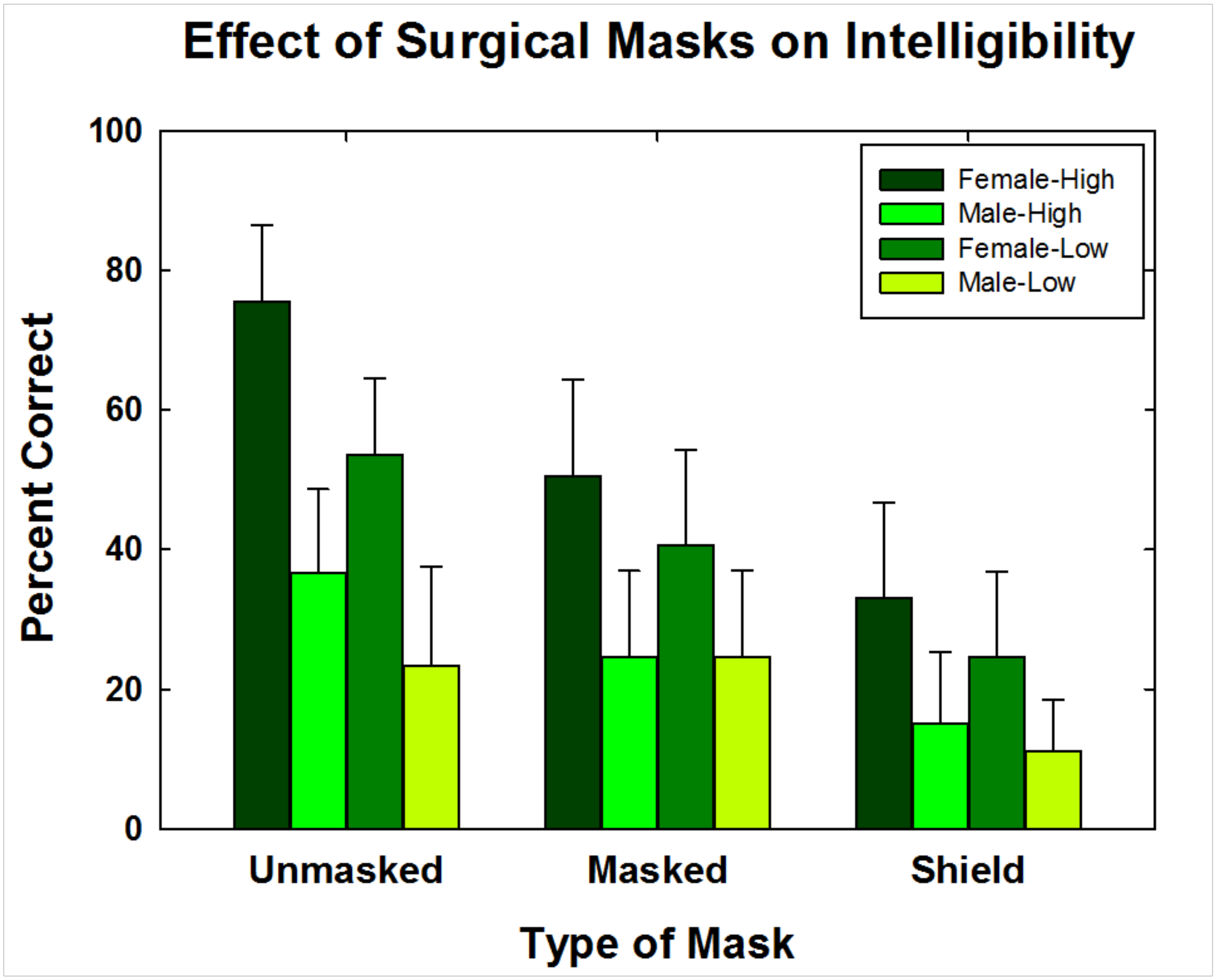

Figure 2: Mean SPIN recognition performance (in percent) for female and male, high and low predictability sentences across listening conditions: unmasked, masked, and shield.

Unmasked					
Male			**Female**		
High Predictability	Low Predictability	Total	High Predictability	Low Predictability	Total
36.6%	23.4%	29.9%	75.4%	29.9%	67.1%
(12.0%)	(14.1%)	(11.3%)	(14.1%)	(11.0%)	(14.5%)
Masked					
Male			**Female**		
High Predictability	Low Predictability	Total	High Predictability	Low Predictability	Total
24.6%	16.8%	20.7%	50.5%	40.6%	45.5%
(12.3%)	(9.9%)	(9.8%)	(13.8%)	(13.6%)	(10.4%)
Shield					
Male			**Female**		
High Predictability	Low Predictability	Total	High Predictability	Low Predictability	Total
15.0%	11.2%	13.1%	33.0%	24.6%	28.8%
(10.3%)	(7.3%)	(7.9%)	(13.7%)	(12.2%)	(11.2%)

Table 1: This table show shows the mean percent correct (standard deviation) of SPIN Test scores averaged for males and females by mask group and predictability across the 21 listeners.

Gender	Mask	Predictability	Mean	Std. Deviation	N
Male	Unmasked	Low Predictability	23.4286	14.10167	21
		High Predictability	36.5714	11.95229	21
		Total	30.0000	14.52332	42
	Masked	Low Predictability	16.3810	10.11176	21
		High Predictability	24.5714	12.28239	21
		Total	20.4762	11.85942	42
	Shield	Low Predictability	11.2381	7.33420	21
		High Predictability	15.0476	10.26877	21
		Total	13.1429	9.02185	42
	Total	Low Predictability	17.0159	11.82601	63
		High Predictability	25.3968	14.40714	63
		Total	21.2063	13.78481	126
Female	Unmasked	Low Predictability	53.4286	14.10167	21
		High Predictability	74.2857	12.36585	21
		Total	63.8571	16.82271	42
	Masked	Low Predictability	40.5714	13.58150	21
		High Predictability	49.1429	12.72119	21
		Total	44.8571	13.70165	42
	Shield	Low Predictability	24.5714	12.21708	21
		High Predictability	32.9524	13.67654	21
		Total	28.7619	13.49220	42
	Total	Low Predictability	39.5238	17.70261	63
		High Predictability	52.1270	21.34773	63
		Total	45.8254	20.53059	126
Total	Unmasked	Low Predictability	38.4286	20.60327	42
		High Predictability	55.4286	22.55091	42
		Total	46.9286	23.10885	84
	Masked	Low Predictability	28.4762	17.02113	42
		High Predictability	36.8571	17.52569	42
		Total	32.6667	17.68079	84
	Shield	Low Predictability	17.9048	12.02398	42
		High Predictability	24.0000	14.99268	42
		Total	20.9524	13.85111	84
	Total	Low Predictability	28.2698	18.77420	126
		High Predictability	38.7619	22.56207	126
		Total	33.5159	21.36991	252

Table 2: This table shows the mean and standard deviation for each effect tested.

Test of Between-Subjects Effects

Dependent Variable Percent

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	78856.556[a]	11	7168.778	48.101	.000
Intercept	283075.063	1	283075.063	1899.387	.000
Gender	38184.143	1	38184.143	256.209	.000
Mask	28430.889	2	14215.444	95.383	.000
Predictability	6935.254	1	6935.254	46.534	.000
Gender * Mask	3494.381	2	1747.190	11.723	.000
Gender * Predictability	280.778	1	280.778	1.884	.171
Mask * Predictability	1388.984	2	694.492	4.660	.010
Gender * Mask * Predictability	142.127	2	71.063	.477	.621
Error	35768.381	240	149.035		
Total	397700.000	252			
Corrected Total	114624.937	251			

a. R Squared = .688 (Adjusted R Squared = .674)

Table 3: This table shows the Test of Between-Subjects Effects for the three main effects tested; the gender of the talker, the speaking condition, and the sentence context.

Chapter 4

Discussion

The first null hypothesis stated that listener performance on a standard test of speech perception in noise would not be affected by the use of a surgical mask or a surgical mask plus a blood-shield. Data analysis allowed us to reject this null hypothesis as the average percent correct across speaking condition decreased as surgical masks and blood-shields were added. Average percent correct across speaking condition were: unmasked (48.5%) > masked (33.1%) > shield (20.9%). Statistical analysis also showed that the speaking condition effect was statistically significant at the 0.01 level. This suggests that the surgical masks and blood-shields worn by health professionals negatively impact speech perception performance. When compared to an individual speaking without a mask, speaking while wearing a surgical mask results in the degradation of speech understanding. Additionally, speaking with a blood-shield added to the surgical mask results in even further degradation of speech understanding.

The second null hypothesis stated that listener performance on a standard test of speech perception in noise would not be affected by the gender of the speaker. Data analysis allowed us to reject this null hypothesis because the average percent correct was much better for the female talker than the male talker, across speaking conditions [female talker (47.1%) > male talker (21.2%)]. Statistical analysis also revealed that the interaction of gender by mask was significant at the 0.01 level. These results suggest that in this study, the female talker was more understandable in the multi-talker babble condition than the male talker. We can speculate that the female talker was easier to understand because the female voice has a naturally higher frequency than the male voice, due to the size and length of the vocal folds. This higher frequency made the female talker's voice easier to pick out from the multi-talker babble than the male talker's voice. In the future, this test will be run with additional male and female talkers to determine if the effect that the female talker was easier to understand than the male talker is consistent, regardless of speaker.

In addition to testing the effect of speaking condition and gender of the talker, of sentence context (high predictability and low predictability sentences) was also studied throughout this experiment. Statistical analysis shows that the average percent correct for high predictability sentences (39.2%) was significantly better than the average percent correct for low predictability sentences (28.4%) at the 0.01 level. Given these data, we can conclude that sentence context affects listener performance across all speaking conditions and for both male and female talkers. In particular, high predictability sentences are easier to understand, regardless of speaking condition and gender of the talker, than low predictability sentences.

Ultimately from the results, we can conclude that surgical masks and blood-shields may be detrimental to speech perception in hospital operating rooms. This experiment was only a small piece of a study to determine the effects surgical masks and blood-shields have on speech perception in operating rooms. In the future, audio recordings will be made of the noises of the operating room during surgery and will serve as the background noise instead of the multi-talker babble. Using actual operating room noise will serve as a more realistic representation of the sounds that interfere with speech during surgery. The same experiment will be performed, however the multi-talker babble will no longer be used. The next experiment will use a larger sample size and include an equal number of male and female subjects. It is important to test both male and female subjects in order to determine if there is a gender effect. In the present study, a there was a difference in results between male and female speakers, therefore a difference may be found in the results between male and female listeners. It is possible that male listeners may identify with the voice of the male speaker and find it easier to hear him in background noise than the female speaker. Further down the road, this experiment will be adjusted so that the effect the surgical masks and blood-shields have on non-native English speakers can be tested and the results compared to the results for native English speakers. There are a large number of health professionals whose first language is not English; therefore it is important to see what effect surgical masks have on their speech intelligibility.

Ultimately, it may be necessary to see what changes can be made to the design and materials of the surgical masks and blood-shields in order to improve speech perception in the hospital operating room. If adjustments to the surgical masks are not feasible, it may be necessary to make adjustments to the signal-to-noise ratio in the operating room environment. Some of the noises in an operating room can be easily eliminated, such as decreasing the volume of the radio played during surgeries, or eliminating the radio altogether. Some of the other noises however, cannot be eliminated at the present time. Many of the beeps, alarms, and other noises from the machines and monitors in an operating room cannot be decreased or eliminated currently due to technology. As technology improves, it is possible that the volume of the machines and surgical tools can be decreased which would improve the signal-to-noise ratio in an operating room. Another potential option to improve speech communication in a hospital operating room would be to have all health professionals wear a headset made up of a microphone and an ear-piece. Health professionals would speak into their microphone and their voice would be heard in the ear-piece of every other health professional in the room. As long as these headsets could be kept sanitary due to operating room standards, this would effectively improve speech communication in hospital operating rooms while allowing music from the radio to still be played. Through continued research, more methods to improve the signal-to-noise ratio and speech communication in hospital operating rooms will be determined.

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